Translation of JP(A)2002-249336

Applied: March 12, 2001
Application No.: P2001-69099
Laid-Open: September 6, 2002
Priority Claim No.: P 2000-98798
Priority Claim Date: March 31, 2000
Priority Claim No.: P 2000-390818
Priority Claim Date: December 22, 2000

TITLE: GLASS

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1. **TITLE OF INVENTION**

Glass

2. **ABSTRACTS**

[Goals]
To offer the glass having a high Young's modulus and high thermal expansion coefficient.

[Solution]
The glass which comprises (in mol%): SiO_2: 1 to 45, TiO_2: 20 to 50, B_2O_3: 0 to 30, Al_2O_3: 0 to 20, MgO: 0 to 20, CaO: 0 to 30, SrO: 0 to 20, BaO: 0 to 30, ZnO: 0 to 20, ZrO_2: 0 to 20, Li_2O: 0 to 15, Na_2O: 0 to 30, and K_2O: 0 to 30.

3. **PATENT CLAIMS**

[Claim 1]
Glass which practically comprises the oxide standards below (in mol%):

SiO_2	1 to 45
TiO_2	20 to 50
B_2O_3	0 to 30
Al_2O_3	0 to 20
MgO	0 to 20
CaO	0 to 30
SrO	0 to 20
BaO	0 to 30
ZnO	0 to 20.
ZrO_2	0 to 20
Li_2O	0 to 15
Na_2O	0 to 30
K_2O	0 to 30.

[Claim 2]
The glass described in Claim 1 of which CaO content is 0 to 20 mol% .

[Claim 3]
The glass described in Claim 1 or 2 of which total content of SrO, BaO, Na_2O and K_2O is at least 10 mol%.

[Claim 4]
The glass described in Claim 1, 2 or 3 of which BaO content is from 3 to 30 mol%.

[Claim 5]
The glass described in one of Claims 1 to 4 of which Na_2O content is from 1 to 30 mol%.

[Claim 6]
The glass described in one of Claims 1 through 5 wherein the SiO_2 content is from 1 to 40 mol% and the TiO_2 content is from 25 to 50 mol%.

[Claim 7]
The glass described in one of Claims 1 to 6 of which liquid phase temperature is at most 1400 °C.

[Claim 8]
The glass described in one of Claims 1 to 7 of which Young's modulus is at least 80 GPa.

[Claim 9]
The glass described in one of Claims 1 to 8 wherein the average linear thermal expansion coefficient from 50 to 350 °C is at least 80×10^{-7}/°C.

[Claim 10]
The glass described in one of Claims 1 to 9 which is the substrate glass.

[Claim 11]
The substrate glass described in Claim 10 wherein the number of the adhered objects with the size of at least 10 μm on the surface is at most $1/cm^2$ and the number of the adhered objects with the size of at least 1 μm but at most 10 μm on the surface is at most $10^5/cm^2$ when the glass substrate made of the said substrate glass is maintained for 20 hours under the 2 atm vapor atmosphere at 120 °C.

[Claim 12]
Information recording medium substrate made of the substrate glass described in Claims 10 or 11.

[Claim 13]
Optical circuit part substrate made of the substrate glass described in Claims 10 or 11.

[Claim 14]
The glass described in one of Claims 1 to 9 which is the glass for the optical lens.

[Claim 15]
Optical circuit part substrate made of the glass of which Young's modulus is at least 100 GPa and the average linear thermal expansion coefficient from 50 to 350 °C is at least 90×10^{-7}/°C.

[Claim 16]
The optical circuit part substrate described in Claim 15 wherein the number of the adhered objects with the size of at least 10 μm on the surface is at most 1/cm^2 and the number of the adhered objects with the size of at least 1 μm but at most 10 μm on the surface is at most 10^5/cm^2 when the glass substrate made of the said glass is maintained for 20 hours under the 2 atm vapor atmosphere at 120 °C.

4. DETAILED EXPLANATION OF INVENTION

[Technical Fields Invention Belongs to]
The present invention relates to the glass which is used as the substrate for the information recording media such as a magnetic disc and optical disc, and for the optical circuit parts such as a band pass filter.

[Conventional Techniques]
Conventionally, the materials for the information recording medium substrate such as the magnetic disc (hard disc) substrate material have been aluminum, glass, ceramics, and carbon. Presently, aluminum and glass are practically utilized depending upon the size and applications. Among them, the application region for the glass substrate is expanding due to the surface smoothness and the good mechanical strength.

The "conventional glass" having the mol% composition of SiO_2: 65.3%, Al_2O_3: 8.6%, 24.2%, ZrO_2: 3.5%, Li_2O: 12.5 %, and Na_2O: 10.1% is the example glass which has been used for such the substrate.

On the other hand, the glass with a high Young's modulus is in demand in order to solve the warping and sagging problems of the information recording medium substrate. As the glass to solve such the problem, JP Kokai H10-81542 discloses the glass having at least 100 GPa of Young's modulus.

Further for the optical circuit parts such as a band pass filter, the substrates made of glass or glass ceramics are employed. For example, the band pass filter for light coupling and splitting in the optical circuit employs the glass ceramic substrate laminated by various ceramic thin films or glass thin films. As such the substrate glass ceramic, the glass having the following composition (in mol%) is exemplified as the "conventional glass ceramics": SiO_2: 74.5%, Al_2O_3: 3.8%, MgO: 1.1%, CaO: 0.1%, ZnO: 0.4%, ZrO_2: 0.6%, Li_2O: 18.1%, Na_2O: 0.1%, K_2O: 1.2%, and P_2O_5: 0.1%. This conventional glass ceramic precipitates crystals such as $Li_2O \cdot 2\ SiO_2$.

[Problems Solved by the Invention]

A magnetic disc utilizes a lot of metallic materials, and the matching of the thermal expansion coefficients of the glass substrate and these metallic materials used at the surrounding is important. For example, the clamp immobilizing the glass substrate is made of metal such as stainless steel. This glass substrate rotates at a high speed during the use as the magnetic disc. At this time, the temperature of the clamp raises to 90 °C or more by the heat generated by the driving motor.

When the difference in the thermal expansion coefficients of the glass substrate and the clamp is larger, there is more possibility to cause the following problems by the temperature increase in this clamp. In other words, the immobilization of the glass substrate by the clamp is loosened or the glass substrate is warped or strained. As a result, the data recording location is shifted, which causes a writing error or a reading error. The average linear thermal expansion coefficient α of the metallic materials at the temperature region from 50 to 350 °C is typically 110 x 10^{-7}/°C.

Further, in order to solve the magnetic disc warping problem, the glass used for the magnetic disc is required to have a high Young's modulus. In the said conventional glass, the α value is 87 x 10^{-7}/°C and the said thermal expansion coefficient matching problem was solved. However, its Young's modulus is 83 GPa, which is not high for the glass substrate for the magnetic disc.

Further in the optical circuit part substrate of which surface is formed by the laminated thin film, the matching of the thermal expansion coefficients for the substrate and the laminated thin film is important. For example, in order to make the temperature dependency of the center wavelength of the light passing through the said optical circuit part (typically from 1530 to 1560 nm) 0.003 nm/°C or less, the α value of the substrate must be at least 80 x 10^{-7}/°C. Further the substrate is also required to have a intensity, i.e., a high Young's modulus, for the grinding and polishing process.

In the said conventional glass ceramics, the α value was 87 x 10^{-7}/°C and the Young's modulus was 94 GPa, which is relatively high. However, in this case, the crystallization process is necessary, which causes more problems in the manufacturing process than the glass. The present invention aims to offer the glass, the information recording medium substrate, and the optical circuit part substrate having a high

Young's modulus and high thermal expansion coefficient, which solves the said problems.

[Method to Solve the Problems]

The present invention offers the glass which practically comprises the oxide standards below (in mol%):

SiO_2	1 to 45
TiO_2	20 to 50
B_2O_3	0 to 30
Al_2O_3	0 to 20
MgO	0 to 20
CaO	0 to 30
SrO	0 to 20
BaO	0 to 30
ZnO	0 to 20
ZrO_2	0 to 20
Li_2O	0 to 15
Na_2O	0 to 30
K_2O	0 to 30.

Further, the present invention offers: the said glass of which CaO content is 0 to 20 mol%; the said glass of which total content of SrO, BaO, Na_2O and K_2O is at least 10 mol%; the said glass of which BaO content is from 3 to 30 mol%; the said glass of which Na_2O content is from 1 to 30 mol%; the said glass wherein SiO_2 content is from 1 to 40 mol% and TiO_2 content is from 25 to 50 mol%; the said glass of which liquid phase temperature is at most 1400 °C; the said glass of which Young's modulus is at least 80 GPa; and the said glass wherein the average linear thermal expansion coefficient from 50 to 350 °C is at least 80×10^{-7}/°C.

Further, the present invention offers: the said glass which is the substrate glass; and the said substrate glass wherein the number of the adhered objects with the size of at least 10 μm on the surface is at most 1/cm^2 and the number of the adhered objects with the size of at least 1 μm but at most 10 μm on the surface is at most 10^5/cm^2 when the glass substrate made of the said substrate glass is maintained for 20 hours under the 2 atm vapor atmosphere at 120 °C.

Further, the present invention offers: the information recording medium substrate made of the said substrate glass; the optical circuit part substrate made of the said substrate glass (the first optical circuit part substrate of the present invention); and the said glass which is the glass for the optical lens.

Further, the present invention offers the optical circuit part substrate made of the glass of which Young's modulus is at least 100 GPa and the average linear thermal expansion coefficient from 50 to 350 °C is at least 90×10^{-7}/°C (the second optical circuit part substrate of the present invention). Further, the present invention offers

the said second optical circuit part substrate of the present invention wherein the number of the adhered objects with the size of at least 10 μm on the surface is at most $1/cm^2$ and the number of the adhered objects with the size of at least 1 μm but at most 10 μm on the surface is at most $10^5/cm^2$ when the glass substrate made of the said glass is maintained for 20 hours under the 2 atm vapor atmosphere at 120 °C.

The inventors of the present invention reached to the present invention by considering that the difficulty to fulfill both the high Young's modulus and high thermal expansion coefficient at the same time in the silicate glass having over 25 mol% of SiO_2 content is originated from the glass structure of the silicate glass or silicate glass ceramics.

[Execution forms of the invention]

The glass substrate of the present invention is suitably used as the substrate. Below, the glass of the present invention which is used for the substrate glass, i.e., the glass of the present invention for the substrate (below referred to as the substrate glass of the present invention) is exemplified for the interpretation.

The substrate glass of the present invention is used as the glass sheet cut into a desired size, i.e. as the glass substrate. The said glass sheet is polished as necessary or polished prior to the said cutting.

The liquid phase temperature, T_L, of the substrate glass of the present invention is desirably at most 1400 °C. The value over 1400 °C may cause the devitrification during the glass manufacturing. The more desirable value is at most 1350 °C, more preferably at most 1300 °C, and most preferably at most 1250 °C.

The Young's modulus E of the substrate glass of the present invention is desirably at least 80 GPa. The value less than 80 GPa may cause the substrate warping and sagging. Further, the intensity of the substrate becomes too low. The more desirable value is at least 90 GPa, preferably at least 100 GPa, more preferably at least 105 GPa, and most preferably at least 110 GPa. When it is used as the information recording medium substrate, this value is desirably at least 100 GPa. Further, the E value is desirably at most 150 GPa. The value over 150 GPa may cause the difficulty in the glass polishing. The desirable value is at most 140 GPa, and more preferably at most 130 GPa.

The average linear thermal expansion coefficient α from 50 to 350 °C of the substrate glass of the present invention is desirably at least 80 x 10^{-7}/°C. The value less than 80 x 10^{-7}/°C may cause the difficulty in the thermal expansion coefficient matching between magnetic disc and metallic clamp, or between the substrate and a band pass filter laminated film. The more desirable value is at most 90 x 10^{-7}/°C, preferably at most 95 x 10^{-7}/°C, more preferably at most 100 x 10^{-7}/°C, most preferably at most 105 x 10^{-7}/°C, and most particularly preferably at most 110 x 10^{-7}/°C.

When the substrate glass of the present invention is used as the substrate for the optical circuit part such as a band pass filter, the average linear thermal expansion coefficient α' from -30 to 70 °C is desirably at least 90×10^{-7}/°C. The more desirable value is at most 95×10^{-7}/°C, and more preferably at most 100×10^{-7}/°C.

Further as the substrate glass of the present invention, the number of the adhered objects with the size of at least 10 μm on the surface, N_L, is desirably at most 1/cm^2 and the number of the adhered objects with the size of at least 1 μm but at most 10 μm on the surface, N_S, is desirably at most 10^5/cm^2 when the glass substrate made of the said glass is maintained for 20 hours under the 2 atm vapor atmosphere at 120 °C.

When N_L exceeds 1/cm^2 or N_S exceeds 10^5/cm^2, the glass substrate surface may have the adhesions (white burn) during the glass substrate storage and the films such as undercoating film, magnetic film, and protection films formed on the glass substrate may be easily peeled off. This adhesion is considered as the reaction product which was formed by the influence of the water and carbon dioxide gas within the air and adhered on the glass surface, and it can not be removed by wiping. The desirable N_L value is at most 0.5/cm^2, and more preferably at most 0.2/cm^2. The desirable N_S value is at most 0.8×10^5/cm^2, and more preferably at most 0.6×10^5/cm^2.

The glass substrate of the present invention desirably have at most 0.90 mg of alkali leaching amount Q (Na_2O mg conversion) measured by the test method defined in "JIS R3502 3.1: Alkali leaching test". The value more than 0.90 mg degrades the performance of the film formed on the glass substrate. Further, the said film tends to peel off easier. The more desirable value is at most 0.80 mg.

The substrate glass of the present invention desirably and practically comprises the oxide standards below (in mol%):

SiO_2	1 to 45
TiO_2	20 to 50
B_2O_3	0 to 30
Al_2O_3	0 to 20
MgO	0 to 20
CaO	0 to 20
SrO	0 to 20
BaO	0 to 30
ZnO	0 to 20
ZrO_2	0 to 20
Li_2O	0 to 15
Na_2O	0 to 30
K_2O	0 to 30.

The substrate glass of the present invention desirably and practically comprises the oxide standards below (in mol%):

SiO_2	20 to 34
TiO_2	28 to 42
B_2O_3	0 to 5
Al_2O_3	0 to 10
MgO	0 to 10
CaO	0 to 10
SrO	0 to 10
BaO	0 to 16
ZnO	0 to 10
ZrO_2	0 to 8
Li_2O	0 to 10
Na_2O	0 to 16
K_2O	0 to 16

wherein the total content of SrO, BaO, Na_2O and K_2O is desirably from 12 to 30 mol%.

Then, the compositions of the substrate glass of the present invention are interpreted by displaying the mol% simply by %. SiO_2 stabilizes the glass and reduces the T_L value, therefore, it is essential. The content more than 45% tends to reduce the E value and/or α. The desirable amount is at most 40%, more desirably at most 38%, and more preferably at most 34%. However, the content less than 1% reduces the glass stability and increase the T_L value. Therefore, the desirable amount is at least 10%, and more desirably at least 20%. When it is used as the optical circuit part substrate, the desirable amount is at least 25%, and more desirably at least 27%.

TiO_2 increase the E value and improves the chemical durability, thus it is essential. The content more than 50% tends to increase the T_L value. The desirable amount is at most 45%, and more preferably at most 42%. However, the content less than 20% reduces the E value and impairs the chemical durability. Therefore, the desirable amount is at least 23%, more desirably at least 25%, and more preferably at least 28%. Particularly when it is used as the optical circuit part substrate, the desirable amount for SiO_2 and TiO_2 are from 1 to 40 mol% and from 25 to 50 mol%, respectively.

B_2O_3 is not essential, but may be comprised up to 30% in order to improve the glass stability and to reduce the T_L value. The amount more than 30% tends to reduce the E and/or α values. The desirable amount is at most 20%, more desirably at most 15%, more preferably at most 10%, and most preferably at most 5%. When B_2O_3 is comprised, the content is desirably at least 1%. The more desirable amount is at least 3%, and particularly preferably at least 5%. It is desirable not comprising B_2O_3 at a practical level when the better chemical durability is desired.

Al_2O_3 is not essential, but may be comprised up to 20% in order to improve the glass stability and to reduce the T_L value. However, the content over 20% may increase the T_L value, and also causes the smaller α or α' value. Therefore, the desirable amount is at most 15%, more desirably at most 10%, and more preferably at

most 5%. When Al_2O_3 is comprised, the content is desirably at least 1%. The more desirable amount is at least 3%, and particularly preferably at least 5%. It is desirable not comprising Al_2O_3 at a practical level when the higher α or α' value is desired.

MgO is not essential, but may be comprised up to 20% in order to increase the E value and to reduce the T_L value. However, the content over 20% may increase the T_L value. Therefore, the desirable amount is at most 15%, and more desirably at most 10%. When MgO is comprised, the content is desirably at least 1%. The more desirable amount is at least 2%, and particularly preferably at least 3%.

CaO is not essential, but may be comprised up to 30% in order to increase the glass stability and to reduce the T_L value. However, the content over 30% may increase the T_L value. Therefore, the desirable amount is at most 20%, more desirably at most 15%, and more preferably at most 10%. When CaO is comprised, the content is desirably at least 1%. The more desirable amount is at least 3%, and particularly preferably at least 5%.

SrO is not essential, but may be comprised up to 20% in order to reduce the viscosity of the molten glass and to reduce the T_L value. However, the content over 20% may increase the T_L value. Therefore, the desirable amount is at most 15%, and more desirably at most 10%. When SrO is comprised, the content is desirably at least 1%. The more desirable amount is at least 3%, and particularly preferably at least 5%.

BaO is not essential, but may be comprised up to 30% in order to stabilize the glass, to increase α or α' value, and to reduce the T_L value. However, the content over 30% may reduce the E value. Therefore, the desirable amount is at most 25%, more desirably at most 20%, and more preferably at most 16%. When BaO is comprised, the content is desirably at least 1%. The more desirable amount is at least 3%, and particularly preferably at least 5%.

ZnO is not essential, but may be comprised up to 20% in order to increase the E value and to reduce the T_L value. However, the content over 20% may increase the T_L value. Therefore, the desirable amount is at most 15%, more desirably at most 10%, and more preferably at most 5%. When ZnO is comprised, the content is desirably at least 0.1%. The more desirable amount is at least 2%, and particularly preferably at least 3%.

ZrO_2 is not essential, but may be comprised up to 20% in order to increase the E value and to stabilize the glass. However, the content over 20% may increase the T_L value. Therefore, the desirable amount is at most 15%, more desirably at most 10%, and more preferably at most 8%. When ZrO_2 is comprised, the content is desirably at least 0.1%. The more desirable amount is at least 1%, and particularly preferably at least 2%.

The total amount of TiO_2 and ZrO_2 is desirably at least 30% when used as the optical circuit part substrate. The value less than 30% makes the E value too small. The more desirable value is at least 32%.

Li_2O is not essential, but may be comprised up to 15% in order to reduce the viscosity of the molten glass, to increase the E value, and also to increase the α or α' value. The amount more than 15% tends to cause the phase separation and may increase the T_L value. The desirable amount is at most 10%, more desirably at most 8%, and more preferably at most 5%. When Li_2O is comprised, the content is desirably at least 0.1%. The more desirable amount is at least 1%, and most desirably at most 2%. It is desirable not comprising Li_2O at a practical level when the lower T_L value is desired.

Neither Na_2O nor K_2O is essential, but each may be comprised up to 30% in order to stabilize the glass, to increase the α or α' value, and to reduce the T_L value. The amount more than 30% tends to cause the small E value. The desirable amount for each is at most 25%, more desirably at most 20%, and more preferably at most 16%. When the higher E value is desired, the content of K_2O is desirably at most 11%, and more preferably at most 8%. When Na_2O or K_2O is comprised, the content of each is desirably at least 1%. The more desirable amount is at least 3%, and most desirably at least 4%. When the lower the T_L value is desired, the containment of Na_2O is desirable and the desirable content is from 1 to 30%.

The total content of BaO and Na_2O is desirably at least 15% for the application as the optical circuit part substrate. The amount less than 15% makes the α or α' value too small. The more desirable amount is at least 18%, more preferably at least 20%, and particularly preferably at least 25%.

The total content of SrO, BaO, Na_2O, and K_2O is desirably at least 10%. The content less than 10% tends to increase the viscosity of the molten glass, reduces the α or α' value, and increases the T_L value. The more desirable amount is at least 12%, more preferably at least 15%, most preferably at least 17%, and particularly most preferably at least 20%. In addition, the said total content is desirably at most 30%. The more desirable value is at most 25%. The said total content is desirably from 17 to 50%, more desirably from 20 to 45%, and more preferably from 25 to 40% for the application as the optical circuit part substrate. The glass substrate of the present invention essentially comprises the said components, however, the other components may be comprised as long as the purpose of the present invention is not impaired. The total content of the said other components is desirably at most 25%, more desirably at most 15%, and particularly preferably at most 10%.

The said other components are discussed. In order to increase the E value, at least one component may be comprised from the group consisting of: V_2O_5, Cr_2O_5, MnO, Fe_2O_3, CoO, NiO, CuO, Ga_2O_3, GeO_2, Y_2O_3, Nb_2O_5, MoO_3, La_2O_3, CeO_2, Pr_2O_3,

Nd_2O_3, Pm_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, HfO_2, Ta_2O_5, and WO_3 (below this group is called as A group). The total content of the group A is desirably at most 20%. The content more than 20% tends to increases the T_L value. The more desirable amount is at most 15%, more preferably at most 10%, and most preferably at most 3%. Further, when the components in the group A are comprised, the total of their contents is desirably at least 0.1%, more desirably at least 1%, and particularly preferably at least 2%.

In order to promote the glass melting and to stabilize the glass, P_2O_5, TeO_2, PbO, and Bi_2O_3 may be comprised. Their total content is desirably at most 10 mol%. Further, SO_3, As_2O_3, and Sb_2O_5, may be comprised as a refining agent. Their total content is desirably at most 2%.

Above, the glass of the present invention was interpreted by using the substrate glass of the present invention. However, the glass of the present invention is not limited to the substrate use and other application such as optical lens is possible. The substrate glass of the present invention is formed into a sheet after the melting and formed into a glass substrate after the annealing and cutting processes. In the present invention, the crystallization process is unnecessary.

Then, the information recording medium substrate and the optical circuit part substrate of the present invention are interpreted. The information recording medium substrate of the present invention is made from the substrate glass of the present invention, which is the glass sheet cut into a desired size and used as the information recording medium substrate. Here, examples of the information recording medium are magnetic disc and optical disc.

The first optical circuit part substrate of the present invention is made of the substrate glass of the present invention, which is the glass sheet cut into a desired size and used as the optical circuit part substrate. The said substrate glass of the present invention desirably has the E value of at least 80 GPa and the α' value of at least 100 x 10^{-7}/°C, or the E value of at least 80 GPa and α value of at least 115 x 10^{-7}/°C. Here, examples of the optical circuit parts are a band pass filter for the light coupling/splitting and gain flattening filter used in the DWDM optical system.

The second optical circuit part substrate of the present invention is made of the substrate glass which has the E value of at least 100 GPa and α value of at least 90 x 10^{-7}/°C. The N_L value and N_S value of the said glass are desirably at most 1/cm^2 and 10^5/cm^2, respectively. The substrate glass of the present invention is an example of such the glass. A laminated thin film is usually formed on the surface of the first and second optical circuit part substrates of the present invention.

Then, the desirable form is discussed when the glass of the present invention is used for the optical lens, particularly for the optical lens manufactured by the heat forming with a mold. The desirable α value is at least 110 x 10^{-7}/°C. When this value is

less than $110 \times 10^{-7}/°C$, it is difficult to remove the glass from the mold after the heat forming and cooling, unless the mold utilizes the low expansion metal such as the ultra-hard alloy. However, the precision processing of the low expansion metal such as the ultra-hard alloy is difficult, thus the improvement in the precision of the mold is also difficult. Therefore, the use of it for the mold is not desirable. The more desirable α value is at least $115 \times 10^{-7}/°C$.

The glass transition point Tg is desirably at most 530 °C. This point higher than 530 °C increases the heat forming temperature. The more desirable value is at most 510 °C. The refractive index n at 587 nm is desirable at least 1.70. Less than 1.70 causes the difficult lens design. The more desirable value is at least 1.75.

The contents of TiO_2 and ZrO_2 are desirably at least 23 mol% and 1 mol%, respectively in order to increase n. The total content of TiO_2 and ZrO_2 is desirably at least 30 mol%. The more desirable value is at least 35 mol%.

For Na_2O and K_2O, the containment of at least one is desirable in order to reduce the T_L value. In this case, the total content of Na_2O and K_2O is desirably at least 10 mol%, more preferably at least 15 mol%.

[Examples]

The raw materials were prepared to form the composition shown in the tables in the rows from SiO_2 to Y_2O_3 by mol%, placed into a platinum crucible, and heated to 1450 to 1650 °C for 3 to 5 hours. At that time, the molten glass was stirred by a Pt stirrer for 2 hours and homogenized. The row of Sr Ba Na K lists the total content of SrO, BaO, Na_2O, and K_2O.

Then, the molten glass was poured, formed into a sheet and annealed. Examples 1 through 56 are Examples of the present invention and Examples 57 and 58 are Comparison Examples. Here, Example 57 is the said conventional glass and Example 58 is the glass disclosed in JP Kokai H10-81542 as Example 3.

For the obtained glasses, density d (unit: g/cm^3), Young's modulus, E (unit: GPa), average linear thermal expansion coefficient from 50 to 350 °C, α, (unit: $10^{-7}/°C$), average linear thermal expansion coefficient from -30 to 70 °C, α', (unit: $10^{-7}/°C$), liquid phase temperature, T_L (unit: °C), the said N_L (unit: number/cm^2), and N_S (unit: number/cm^2) were measured. The measurement methods for d, E, α, α', T_L. N_L and N_S are as follows. The results are shown in the tables. Within the table "-" indicates that there is no data.

d: Measured for about 20 g of glass by the Archimedes' method. The d value is desirably at most 3.9 g/cm^3, more desirably at most 3.8 g/cm^3.

E: Measured for a sheet-like sample with a size of 4 cm x 4 cm and a thickness of 10 to 20 mm, of which both sides are polished in parallel, by the ultrasonic pulse method.

α and α': The column-like sample with 5 mm diameter and 20 mm length was measured by heating from 50 °C to +350 °C and from -30 to +70 °C at the rate of 5 °C/min by using a thermal mechanical analysis device (manufactured by Rigaku, trade name of TMA 8140) and the average linear thermal expansion coefficients were calculated. The α value for Examples 36 to 46 were calculated based on the composition.

T_L: Glass was crushed to 2 mm size by mortar and the glass particles were placed on a platinum boat. This Pt boat was heat treated for 24 hours within the temperature gradient furnace. The highest temperature location at which the glass particle had crystal precipitation was taken as the liquid phase temperature.

N_L and N_S: A sheet-like sample with a size of 4 cm x 4 cm and a thickness of 1 to 2 mm, of which both sides are mirror polished was washed with calcium carbonate and neutral detergent. Then it was placed in a ultra-accelerated lifetime tester (unsaturated type pressure cooker TPC-410, manufactured by Tabaie Spec) and left at 2 atm vapor atmosphere at 120 °C for 20 hours. A 200 μm square on the surface of the taken out glass sheet was observed with differential interference microscope and the number of the adhered objects with the size of 10 μm or more and with the size of 1 μm to 10 μm was counted. The N_L and N_S values were calculated from these numbers.

Further for Examples 39 and 40, Tg, n, and Q were also measured. Tg values for Examples 39 and 40 are 510 °C and 497 °C, respectively. The n values for Examples 39 and 40 are 1.79 and 1.78, respectively. And the Q values for Examples 39 and 40 are 0.36 mg and 0.61 mg, respectively.

[Effects of Invention]

The present invention offers the information recording medium such as magnetic disc in which the troubles such as the writing and reading errors hardly occur. Further, the present invention offers the optical circuit part such as the band pass filter having a high intensity and a small temperature dependency. Further, the glass substrate for the information recording medium and the glass substrate for the optical circuit part which requires no crystallization process and less manufacturing processes compared to the glass ceramic substrate are offered.

Further, the glass substrate for the information recording medium and the glass substrate for the optical circuit part, which offers the superior weather resistance and generates little adhered objects during the storage, are offered. Therefore, the peeling of the undercoat film, magnetic film, and protection film caused by these adhered objects hardly occurs. Further, the glass for the optical lens which can be heat formed by the mold made of the metal besides the low expansion metal is offered.

Table 1

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Ex. 11
SiO_2	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	33.0	33.0
TiO_2	33.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	33.0	37.0	37.0
Al_2O_3	0	0	0	0	0	0	0	0	0	0	0
MgO	0	0	0	0	0	0	0	5.0	2.0	0	3.0
CaO	6.0	5.0	7.5	5.0	5.0	7.5	7.5	5.0	6.0	6.0	0
SrO	6.0	5.0	7.5	7.0	10.0	7.5	7.5	7.0	6.0	6.0	6.0
BaO	11.0	10.0	15.0	10.0	5.0	0	10.0	5.0	11.0	11.0	11.0
ZnO	0	0	0	0	0	0	0	0	2.0	0	3.0
ZrO_2	7.0	0	0	0	0	0	0	0	3.0	3.0	3.0
Li_2O	0	4.0	0	8.0	4.0	0	0	0	0	0	0
Na_2O	7.0	6.0	0	0	6.0	15.0	5.0	8.0	7.0	4.0	4.0
K_2O	0	0	0	0	0	0	0	0	0	0	0
Y_2O_3	0	0	0	0	0	0	0	0	0	0	0
SrBaNaK	24.0	21.0	22.5	17.0	21.0	22.5	22.5	20.0	24.0	21.0	21.0
d	3.79	3.65	3.83	3.73	3.59	3.29	3.73	3.52	3.75	3.75	3.79
E	107	112	108	117	113	102	107	109	105	108	107
α	97	103	90	95	100	108	97	99	102	91	90
α'	-	-	-	-	-	-	-	-	-	-	-
T_L	1260	1130	1180	1140	1210	1260	1220	1170	1230	1180	1270
N_L	0	-	-	-	-	-	-	-	-	-	-
N_S	0.2	-	-	-	-	-	-	-	-	-	-

Table 2

	Ex. 12	Ex. 13	Ex. 14	Ex. 15	Ex. 16	Ex. 17	Ex. 18	Ex. 19	Ex. 20	Ex. 21	Ex. 22
SiO_2	30.0	30.0	30.0	30.0	30.0	26.0	32.5	42.0	30.0	30.0	28.0
TiO_2	40.0	33.0	33.0	36.0	36.0	36.0	32.6	28.0	33.0	36.0	36.0
Al_2O_3	0	0	0	0	0	0	0	0	0	0	0
MgO	3.0	0	0	0	0	0	0	0	0	0	0
CaO	0	6.0	6.0	2.0	0	0	8.8	6.7	0	0	0
SrO	6.0	6.0	6.0	6.0	4.0	6.0	8.8	6.7	6.0	6.0	6.0
BaO	11.0	11.0	15.0	12.0	14.0	12.0	8.8	6.7	17.0	14.0	12.0
ZnO	3.0	0	0	0	0	0	0	0	0	0	0
ZrO_2	3.0	3.0	3.0	3.0	3.0	3.0	3.5	0	3.0	3.0	3.0
Li_2O	0	0	0	0	0	0	0	0	0	0	0
Na_2O	4.0	7.0	7.0	7.0	9.0	7.0	2.5	10.0	7.0	7.0	7.0
K_2O	0	4.0	0	4.0	4.0	10.0	2.5	0	4.0	4.0	8.0
Y_2O_3	0	0	0	0	0	0	0	0	0	0	0
SrBaNaK	21.0	28.0	28.0	29.0	31.0	35.0	22.7	23.3	34.0	31.0	33.0
d	3.83	3.62	3.82	3.66	3.64	3.52	3.67	3.41	3.76	3.67	3.61
E	110	96	101	98	93	81	104	100	91	94	87
α	90	106	103	103	110	124	93	98	108	100	116
α'	-	-	-	-	-	-	-	-	-	-	-
T_L	1280	-	-	-	-	-	-	-	-	-	-
N_L	-	-	-	-	-	-	-	-	-	-	-
N_S	-	-	-	-	-	-	-	-	-	-	-

Table 3

	Ex. 23	Ex. 24	Ex. 25	Ex. 26	Ex. 27	Ex. 28	Ex. 29	Ex. 30	Ex. 31	Ex. 32	Ex. 33
SiO_2	28.0	36.0	28.0	32.0	34.0	30.0	42.0	42.0	42.0	29.0	28.0
TiO_2	38.0	24.0	37.0	33.0	36.0	36.0	28.0	28.0	28.0	33.0	30.5
Al_2O_3	0	3.0	0	0	0	0	0	0	0	0	0
MgO	0	0	0	0	0	0	0	0	0	0	0
CaO	0	1.4	6.0	8.0	4.0	0	11.0	4.5	4.5	4.0	6.5
SrO	2.0	5.4	6.0	10.0	6.0	6.0	4.5	11.0	4.5	0	0
BaO	12.0	21.7	13.0	8.0	10.0	12.0	4.5	4.5	11.0	19.0	17.0
ZnO	0	0	0	0	0	0	0	0	0	0	0
ZrO_2	3.0	3.5	7.0	7.0	7.0	3.0	0	0	0	3.0	3.0
Li_2O	0	0	0	0	0	0	0	0	0	0	0
Na_2O	7.0	5.0	3.0	2.0	3.0	7.0	10.0	10.0	10.0	4.0	9.0
K_2O	10.0	0	0	0	0	6.0	0	0	0	8.0	6.0
Y_2O_3	0	0	0	0	0	0	0	0	0	0	0
SrBaNaK	31.0	32.1	22.0	20.0	19.0	31.0	19.0	25.5	25.5	31.0	32.0
d	3.47	3.89	3.94	3.80	3.77	3.57	3.27	3.39	3.49	3.66	3.63
E	83	94	110	111	109	91	99	99	97	84	85
α	118	94	90	88	81	107	97	98	99	111	119
α'	-	-	-	-	-	-	-	-	-	-	104
T_L	-	-	-	-	-	-	-	-	-	-	1170
N_L	-	-	-	-	-	-	-	-	-	-	-
N_S	-	-	-	-	-	-	-	-	-	-	-

Table 4

	Ex. 34	Ex. 35	Ex. 36	Ex. 37	Ex. 38	Ex. 39	Ex. 40	Ex. 41	Ex. 42	Ex. 43	Ex. 44
SiO_2	27.5	27.0	27.5	28.0	28.0	30.0	30.0	29.1	29.5	30.0	31.0
TiO_2	29.5	29.0	30.0	30.0	30.5	33.0	33.0	33.0	33.0	33.0	33.0
Al_2O_3	0	0	0	0	0	0	0	0	0	0	0
MgO	0	0	0	0	0	0	0	0	0	0	0
CaO	6.5	6.5	6.5	1.0	6.5	0	0	0	0	0	0
SrO	1.5	2.5	0	5.0	0	0	0	0	0	5.0	0
BaO	17.0	17.0	18.0	18.0	16.0	14.0	12.0	14.0	12.0	9.0	11.0
ZnO	0	0	0	0	0	0	0	0	0	0	0
ZrO_2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Li_2O	0	0	0	0	0	0	0	0	0	0	1.0
Na_2O	8.0	8.0	9.0	9.0	11.0	15.0	15.0	14.9	15.5	13.0	14.0
K_2O	7.0	7.0	6.0	6.0	5.0	5.0	7.0	5.0	6.0	7.0	7.0
Y_2O_3	0	0	0	0	0	0	0	1.0	1.0	0	0
SrBaNaK	33.5	34.5	33.0	38.0	32.0	34.0	34.0	33.9	33.5	34.0	32.0
d	3.63	3.64	3.65	3.70	3.59	3.49	3.39	3.51	3.43	3.40	3.36
E	83	83	84	83	85	83	80	84	83	83	83
α	121	123	121	121	120	121	124	121	122	120	120
α'	103	106	103	107	104	107	111	109	107	109	106
T_L	-	-	-	-	1200	1100	1110	-	-	1300	1120
N_L	-	-	-	-	-	-	-	-	-	-	-
N_S	-	-	-	-	-	-	-	-	-	-	-

Table 5

	Ex. 45	Ex. 46	Ex. 47	Ex. 48
SiO_2	31.0	34.0	28.0	36.0
TiO_2	33.0	30.0	42.0	24.0
Al_2O_3	0	0	0	0
MgO	0	0	0	0
CaO	0	2.5	4.4	25.1
SrO	1.0	0	17.7	6.3
BaO	10.0	8.0	4.4	1.6
ZnO	0	0	0	0
ZrO_2	3.0	3.0	3.5	7.0
Li_2O	2.0	2.0	0	0
Na_2O	12.0	12.0	0	0
K_2O	8.0	8.5	0	0
Y_2O_3	0	0	0	0
SrBaNaK	31.0	28.5	22.1	7.9
d	3.35	3.24	3.87	3.52
E	84	84	114	113
α	120	119	84	84
α'	107	106	-	-
T_L	1130	1110	-	-
N_L	-	-	-	-
N_S	-	-	-	-

Table 6

	Ex. 49	Ex. 50	Ex. 51	Ex. 52	Ex. 53	Ex. 54	Ex. 55	Ex. 56	Ex. 57	Ex. 58
SiO_2	39.0	34.0	40.0	39.0	37.5	38.0	38.5	39.0	65.3	40.0
TiO_2	26.0	30.0	26.0	26.0	26.0	26.0	26.0	26.0	0	5.0
Al_2O_3	0	0	0	0	0	0	0	0	8.6	25
MgO	0	0	0	0	0	0	0	0	0	25
CaO	0	2.5	4.5	4.5	5.5	5.0	5.0	5.0	0	0
SrO	1.5	0	0	0.5	2.0	2.0	2.0	0	0	0
BaO	11.0	8.0	5.0	4.5	4.0	4.0	4.0	5.0	0	0
ZnO	0	0	0	0	0	0	0	0	0	0
ZrO_2	0	3.0	0	0	0	0	0	0	3.5 ?	0
Li_2O	2.0	2.0	2.0	3.5	4.5	4.0	4.0	4.5	12.5	0
Na_2O	18.0	12.0	18.0	18.0	19.0	18.0	18.5	18.5	10.1	0
K_2O	2.5	8.5	4.5	4.0	1.5	3.0	2.0	2.0	0	0
Y_2O_3	0	0	0	0	0	0	0	0	0	5
SrBaNaK	33.0	28.5	27.5	27.0	26.5	27.0	26.5	25.5	10.1	0
d	3.31	3.24	3.06	3.06	3.10	3.08	3.09	3.05	2.48	3.06
E	85	85	84	87	92	89	90	91	83	124
α	124	116	125	130	135	135	133	130	87	63
α'	111	101	110	109	111	108	105	107	-	-
T_L	<1050	1120	<1000	980	1070	1080	1080	1050	-	-
N_L	-	-	-	-	-	-	-	-	2×10^4	-
N_S	-	-	-	-	-	-	-	-	4.0	-